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Wildland Research Plan For California

STATE OF CALIFORNIA
RESOURCES AGENCY
DEPARTMENT OF CONSERVATION
DIVISION OF FORESTRY

in cooperation with

UNIVERSITY OF CALIFORNIA, SCHOOL OF FORESTRY AND CONSERVATION

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION AND CALIFORNIA REGION

U.S. DEPARTMENT OF INTERIOR NATIONAL PARK SERVICE BUREAU OF LAND MANAGEMENT

Revised December 1969

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FOREWORD

A little more than 10 years ago, the State Board of Forestry asked: "Given a finite land area and increasing population, what knowledge is needed for wise management of California's 60 million acres of wildland in the years ahead?"

The answer became the *Wildland Research Plan For California*, published in 1958. It gave the people of California—for the first time—a comprehensive picture of the many natural resources, products, and uses to be derived from the state's millions of acres of undeveloped grass, brush, and timber covered lands lying in the foothills, mountains, and deserts. It also described the many wildland resource management problems, the research underway to solve them, and the additional research needed to cope with increasing demands for timber, water, forage, and outdoor recreation. It provided a benchmark for coordinated planning by private and governmental agencies. And it stimulated additional support for research.

But the increase in research effort was spotty, and five years later the total effort still fell short. "Between 1958 and 1963," a 1964 revision of the *Plan* reported, "we have closed less than half the gap between research effort and the minimum needs recognized by the 1958 plan. While the problems requiring research have become even more severe, our wildland research effort is lagging."

Another five years have passed, and another appraisal is called for. The land is still limited; indeed, in many localities less land is available for production of food and fiber because of reservations for highways, recreational and residential areas, or other special purposes.

Although California's annual population growth rate has decreased from its peak of a few years ago, that rate continues to exceed the national average. Also, the increasing income, leisure time, and mobility of California's growing population is reflected in a rising use of the state's wildlands. In the past five years there has been an annual increase of 6 to 15 percent in various kinds of recreational use of the wildland environment.

An improved highway system speeds recreationists to the mountains in a fraction of the time required 10 years ago. Truck campers and trailers, boats and snowmobiles, jeeps and motorcycles all place people in situations that create new problems for the wildland resource manager and contribute to a deteriorating wildland environment. At the same time public pressure is mounting for greater emphasis on an important dimension in resource management—quality of the environment.

Management of California's wildlands has therefore taken on new meanings in recent years. The impact of any one management action may have important short-range and long-range effects on many aspects of the total environment. The many disciplines of scientific research become more interdependent and interacting than ever. New challenges arise as researchers and wildland managers strive together to meet man's needs in today's rapidly changing world.

In light of these changing needs and the mounting emphasis on the total wildland environment, the State Board of Forestry requested this 1969 revision of the *Plan*. It was prepared by the Wildland Research Planning Committee convened by W. B. Carter, Chairman of the State Board of Forestry, who also served as chairman of this committee. Members of the committee were: John Zivnuska, Dean of the University of California School of Forestry and Conservation; Fred Dickinson, Director of the University of California Forest Products Laboratory; Robert D. McCulley, Director of the U.S. Forest Service's Pacific Southwest Forest and Range Experiment Station; J. W. Deinema, Regional Forester of the U.S. Forest Service; John Callaghan, Secretary-Manager of the California Forest Protective Association; Robert T. Radford, Chairman of the Los Angeles County Watershed Commission; James Stearns, Director of the California Department of Conservation; Paul Aurignac, member of the State Board of Forestry; and Francis H. Raymond, State Forester. The *Plan* reflects existing research and projected needs expressed by the U.S. Forest Service, the National Park Service, the Bureau of Land Management, the Agricultural Experiment Station of the University of California, representatives of certain privately owned wildlands, and the California Division of Forestry. The Committee recognizes that the *Plan* does not reflect *all* wildland research being conducted in California, although it believes that the major portion of such effort has been included. Time and practicality did not permit contacting the many other agencies that conduct wildland research as a part of their day-to-day activities.

The committee urges rapid implementation of the *Plan* so that California's wildlands can continuously yield products and services that are relevant to the needs and economic welfare of the people. This implementation requires the allotment of additional funds to wildland research efforts. Without these funds, research and, consequently, management capabilities in the protection and development of wildland resources will fall farther and farther behind the pace set by the people themselves in their rapidly changing demands upon the use of California's wildlands.

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Research effort recommended in 1958
100%
Level achieved in 1958
54%
Level achieved in 1963
74%
Level achieved in 1968
78%
Research effort recommended for 1975
172%

Summary Of Findings

Since the *Wildland Research Plan for California* was first published in 1958, the needs for research in how to manage and use wildland resources have continued to grow at a compounding rate. These needs are a reflection largely of the state's burgeoning population and the increasing dependency of that population upon the many products and uses to be derived from the wildlands.

More people means a growing demand for homes built from wood and for many other products made from natural or processed wood; a need for space to build those homes, space that often can be carved only from the wildlands; a desire for room to roam, to recreate, and to renew the spirit; a requirement for more food, much of which comes from livestock or wild game dependent on wildland forage; a need for more water, accumulated and stored as snow in the forested mountains of California.

At the same time that the growing population of California looks to the state's wildlands for more useable products, there is also a rising demand for an improved quality of the wildland environment. Rivers and lakes with cleaner water, skies free from polluting smoke and gases, and areas set aside for their natural beauty or for the preservation of wild animals and birds—these things, too, are required by the people.

And so the need for wildland research multiplies proportionately, and the job of the researcher becomes more complex. The question posed to the researcher once was, "How can we use the resources of California's wildlands?" Now the question is, "How can we intensify and increase our use of wildland resources from a decreasing land base and at the same time provide for more beauty, recreation, and the preservation of natural areas?" The answer is difficult to attain and can be provided only by study and investigation of the critical elements.

This 1969 revision of the *Wildland Research Plan for California* describes some of the problems facing the wildland researcher today, some of the progress he has made since the last reporting in 1964, and the more important needs for additional research that are needed now and estimated to be needed by 1975. The Wildland Research Planning Committee, representing private and governmental wildland management and research agencies, recommends prompt action to expand research effort to at least the level recommended in the 1958 Wildland Research Plan. To achieve this minimum and out-dated goal will require the equivalent funding of an additional 57 fulltime professional wildland researchers.

Trends in Wildland Problems

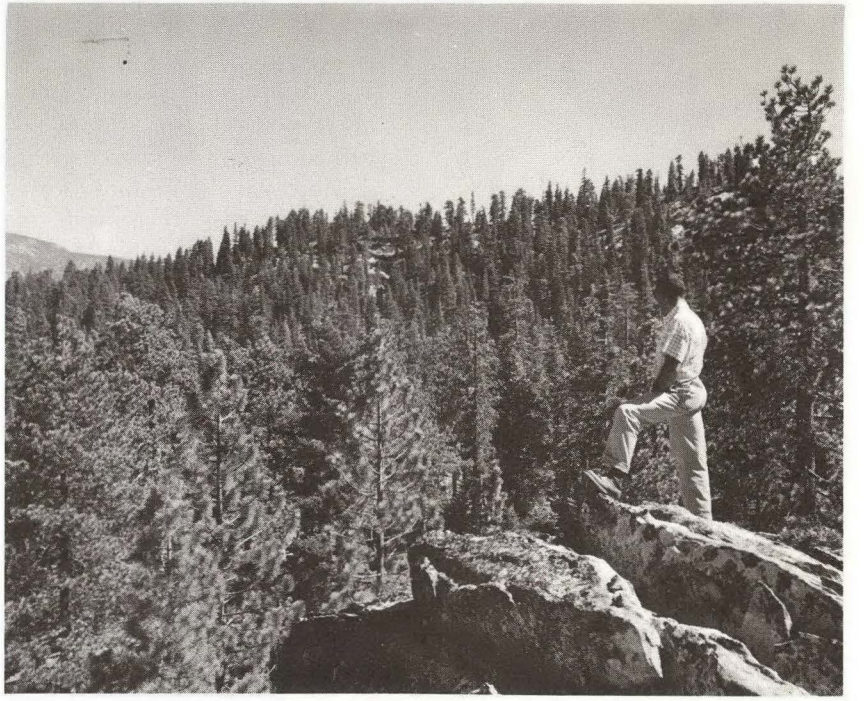
California is noted for its variety of climate, topography, soil and vegetation. This variety results in many different environments: the wet coastal redwood strip, the moist mixed-conifer forest of the Sierra Nevada, the semi-arid brushfields of southern California, the dry southeastern desert, to name a few. Each environment develops its own biological community of plants, animals, and micro-organisms, and together they strike a balance that tends to perpetuate the community. These many ecological systems, or "ecosystems," are the basic wealth of California.

Man is part of the ecosystem, and in recent years he has become increasingly aware of his ability to influence the quality of his environment. Pleas for clean water, pure air, and more care for the visual impact of man's activities are common. Moreover, a national survey has indicated that a strong majority of the public is willing to pay more taxes to improve their surroundings. Legislators and administrators have responded with measures to control air and water pollution, create new parks and recreation areas, protect amenity values in urban and rural areas, strengthen conservation education in public schools, and provide for continuing study of environmental quality problems.

At the same time, man's increasing numbers have led to intensified demands for the goods and services his environment provides. For example, the people of California continue to use forest products at the highest per capita rate of any population group in the world. However, few urbanites equate their demands with the trees in the forest. On the one hand they exclaim, "Give us more homes, more furniture, more paper." On the other hand they decry the felling of a single tree, not recognizing that trees are a renewable resource. Thus we must look for resource management practices that consider both quality and quantity of production if all the uses of the wildlands are to be sustained.

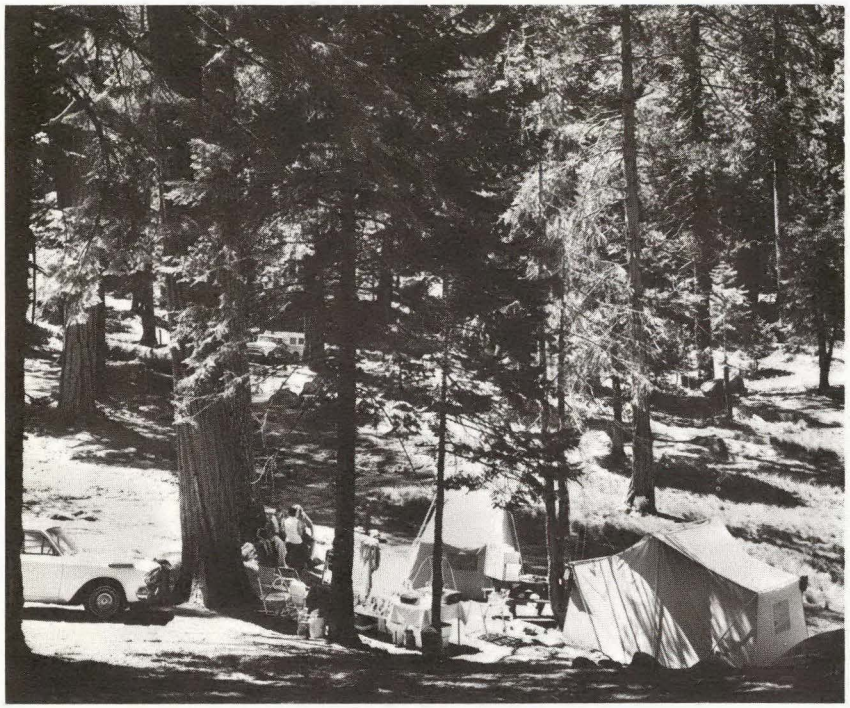
As a result, research faces demands for new kinds of information. Planners and land managers are asking: "How can more and more people find enjoyment and reap a living from finite wildland resources—and at the same time protect and enhance complex ecological systems?" There are few easy answers. But the search for answers is urgent, as the State Office of Planning has pointed out—

> ". . . sufficient attention has not been given to the effects of population increase and other growth factors on the state's resources and amenities. There is still time; but the obstacles to planning and to freedom of choice increase with each passing year."



Man is a part of California's wildland environment. In recent years he has become increasingly aware of his ability to influence the quality of that environment.

In looking ahead, planners are confronted with demands upon the wildlands which greatly complicate the choices to be made. Occupancy of wildlands brought about by urban sprawl, establishment of areas devoted exclusively to parks and recreation, and other special reservations bring repercussions far beyond the boundaries of such areas. New highways need to be accommodated. Communication systems, power lines, reservoirs, and sanitation and water systems are needed. Planning for these and other developments calls for new surveys and for research into new techniques to boost productivity and balance the output of products and services from wildland resources. The wildland



Increasing use of the state's wildlands and wildland resources creates problems of protecting and enhancing the quality of complex ecological systems.

The wildland manager needs more facts in greater detail about all parts of the wildland ecosystem if he is to make correct decisions about the current and future use of each acre and its resources.

manager needs more facts in greater detail, along with the facilities for updating and analyzing them rapidly, if he is to make correct decisions about the current and future use of each acre of wildland.

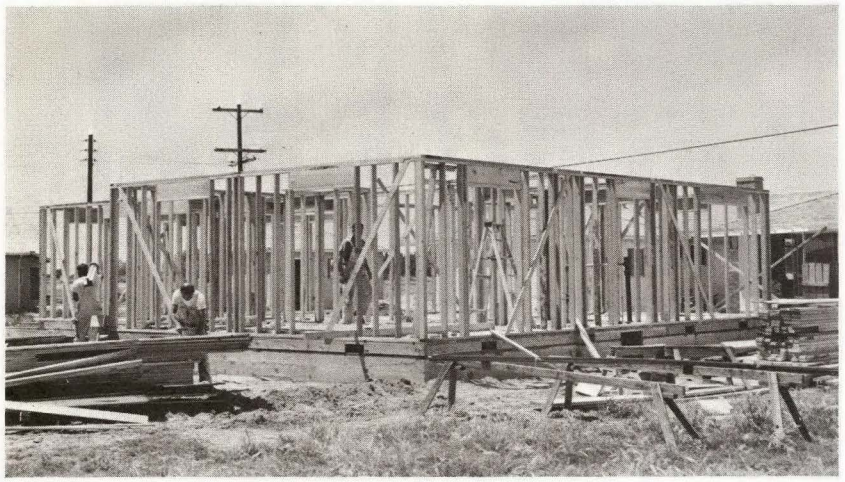
Timber Management

The complexity of decision-making in all wildland management is exemplified in the problems of timber management. Production of wood is a mainstay of the economy in several northern counties, and requirements for wood products grow with the population. The planned expansion in national housing programs will place even more demands on California timber. But the forest manager must balance timber growing and harvesting needs against demands for water, forage, outdoor recreation, wildlife, and esthetic forest environments.

Integrating such uses of wildland calls not only for modified practices to meet special interests, but also—with timber production reduced by inroads on commercial forest acreage and adjustments for multiple uses—for intensified management on the remaining commercial acreage. Ecological knowledge to guide such environmental forestry has become particularly important for redwood and mixed-conifer forests. More emphasis is needed on research to improve forest trees by selection and breeding and to achieve optimum growth and wood quality by soil amendments, thinning, planting, or other cultural practices. Furthermore, efficiency of production will require detailed plans based on current, accurate resource information and increased ability to apply computer-based analytical systems for efficient planning and resource allocation.

Wood Products

The demand for timber products has tended upward in recent years in both domestic and export markets. This trend has brought increasing competition for raw material and opened the door to use of smaller trees, additional species of trees, and more complete use of the material



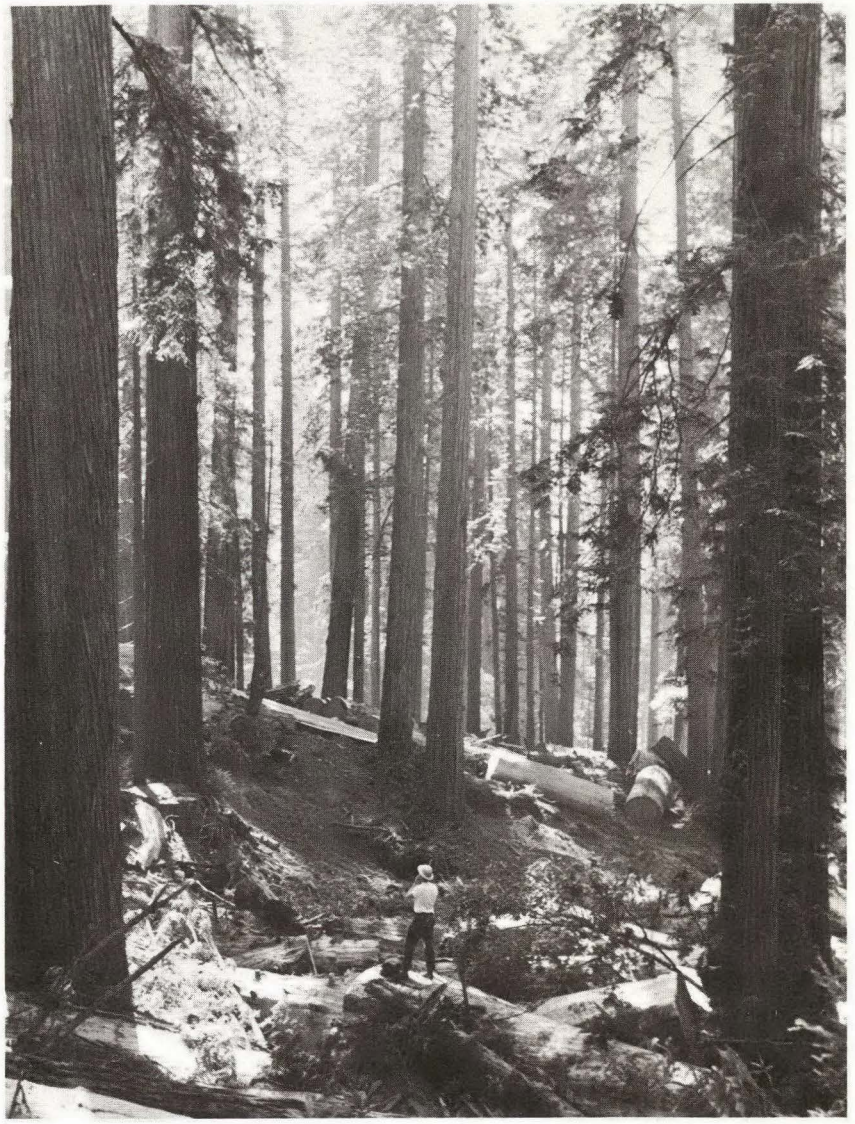
Planned expansion in national housing programs will place even more demands on California timber.

harvested. Research emphasizing use of such material for wood, fiber, and chemical products would help stabilize forest industries and aid their adjustment from an old-growth timber economy. Particular attention to the use or elimination of manufacturing residuals is desirable to reduce the potential for air and water pollution resulting from long-used waste disposal practices.

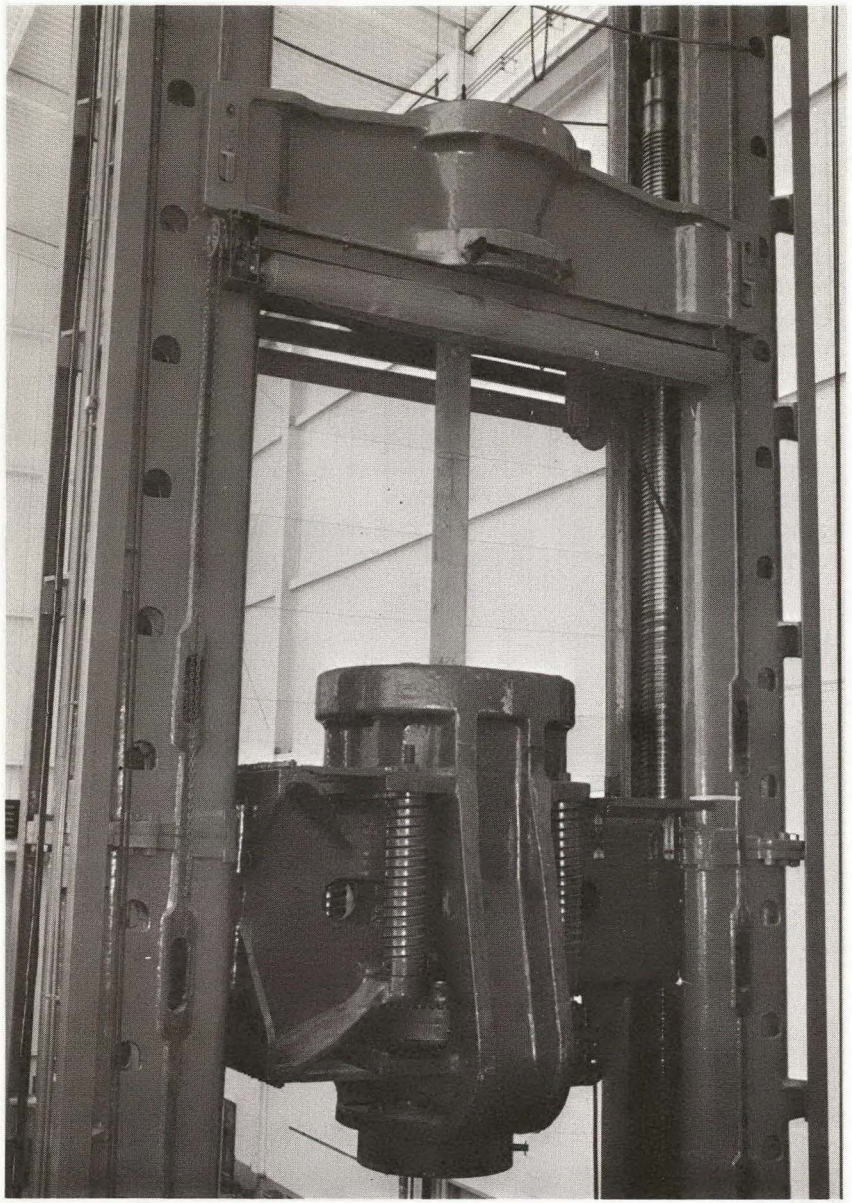
The competition for raw material has been accompanied by rising prices, and manufacturers and users of wood products have expressed concern about the adequacy of supplies. Increased demand for low-cost housing and for non-timber uses of forest land underline their concern. Both manufacturers and users could benefit from research aimed at greater efficiency in raw material conversion systems, including new equipment, computerized decision-making techniques, and the assembly of components and complete structures.

Range Management

The pressure on wildland is eliminating or severely restricting livestock grazing use in many areas while the demand for meat and other livestock products is increasing. Much of this demand is being met through increased use of feedlots and irrigated pasture. However, increased production of range forage, through such means as use of fertilizers and improved grass strains, is a necessary part of the total production pattern. The most striking change is increasing recognition that judicious grazing management can help meet other wildland problems, such as reduction of fire hazard, control of brush species, reduction of competition to trees in young timber stands, and maintenance



Integrating timber production with other demands on forest acreage calls for more knowledge about intensified management of those lands.



Testing the strength and other characteristics of heretofore little-used native wood species is needed to determine how these woods may help meet today's growing demand for timber products.

of an esthetically pleasing landscape. Range management research is no longer placing emphasis solely on livestock production values but is involved in the total, integrated, management of wildland ecosystems.

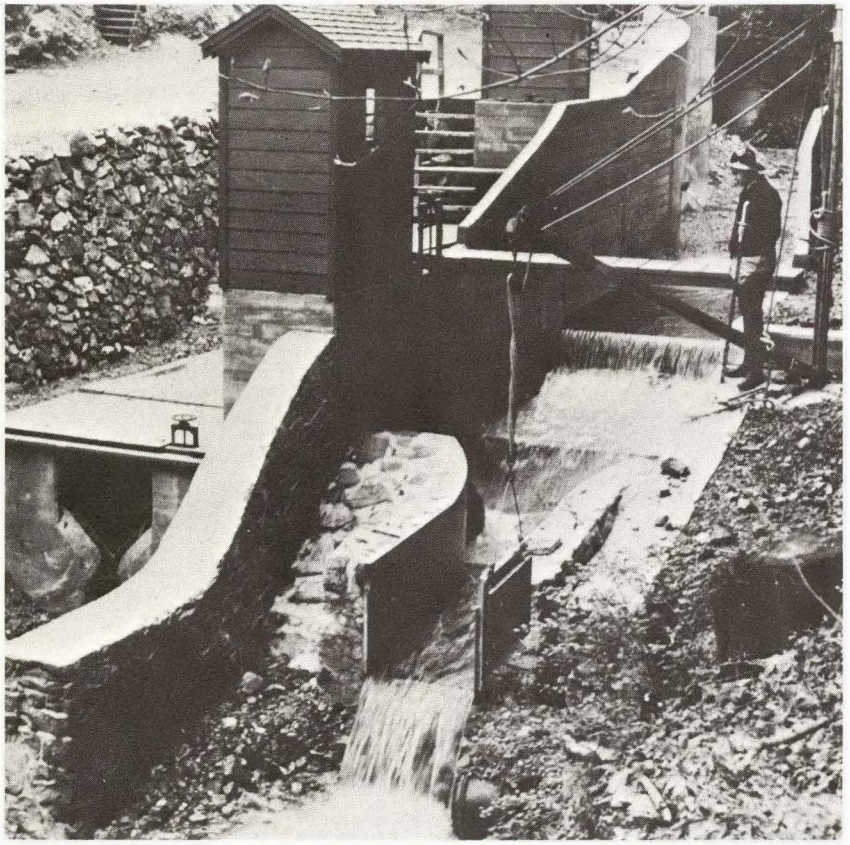
Watershed Management

The urgency of maintaining and improving the quality of water has led to federal and state legislation and administrative orders to control degradation of water. Sediment loads and water temperature, as well as chemical and biological pollutants, are important water quality factors in watershed management. In most cases, quality is becoming just as important as quantity. It is essential, therefore, that future research considers the quality of water as well as the quantity and timing of water yield. Particular emphasis seems advisable on measures to aid soil stabilization and reduce the risks of pollution under intensive land management and increased use of wildland for recreation and community development.

More scientific management is needed on the decreasing acreage available for livestock grazing.

Wildlife Habitat Management

California's population is placing unprecedented demands upon public and private wildland for wildlife-associated recreation. This demand trend shows no sign of slackening. If future recreational demands are to be met, increased attention to improvement of wildlife habitat is more urgent than ever before. Both game and non-game species as well as fish deserve attention. Wildlife habitat improvement blends well with other phases of wildland management. The major research emphasis should be placed on knowledge and techniques that can be applied within a broad management framework.



The need for water quality has become as important as the quantity and timing of water yield.

Recreation

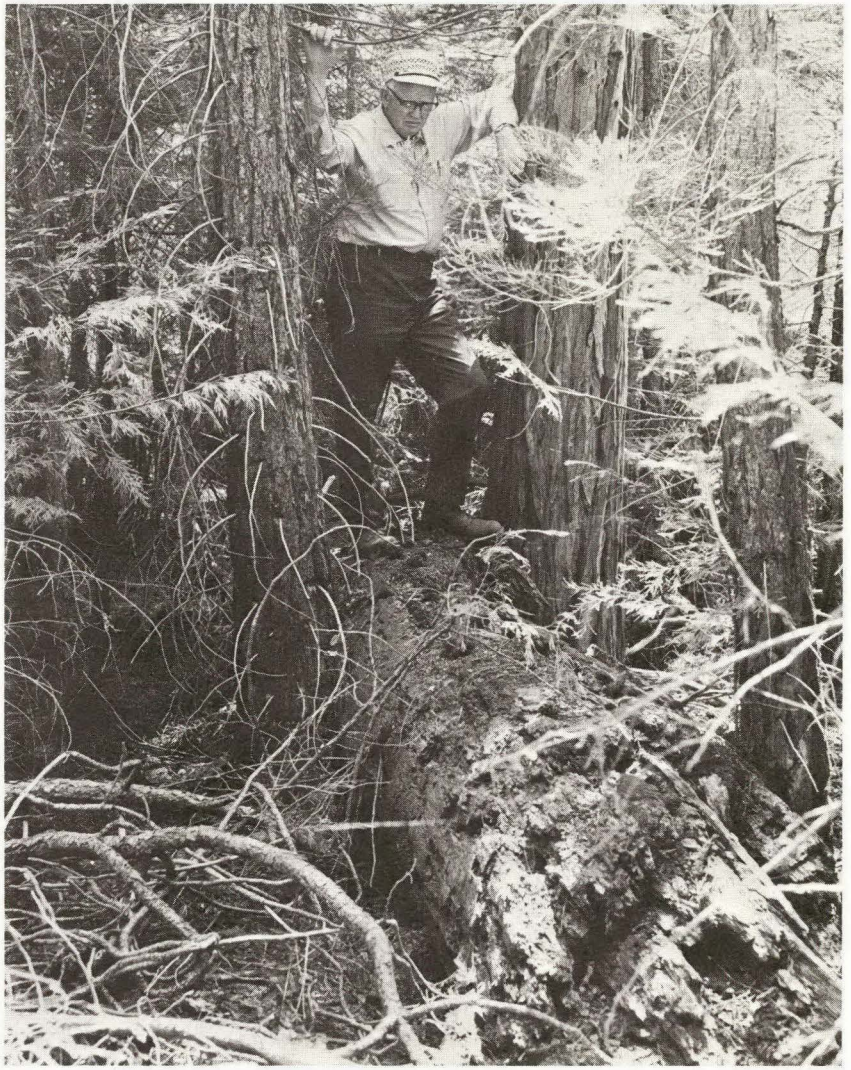
Recreational use of California's wildland continues upward as more tourists learn about the state's superlative attractions and more residents seek respite from the tensions of an increasingly urban society. The resulting demands have long passed the point where they can be accommodated quickly at little cost: more land dedicated to wilderness, parks, and open space; more rapid development of facilities to accommodate the multitudes who want a less primitive type of recreation than the wilderness enthusiasts; more action to make the benefits of outdoor recreation more readily available to city dwellers unable to travel into the hinterland. Such needs stimulate increasingly sharp conflicts between recreation and production of other necessary products and services from the state's wildlands. Such conflict places a premium on research to provide the economic and ecological information required for wise land use planning. Equally urgent are the development of methods to protect or enhance landscape amenities, practices to prevent damage to wildland environments by over-use, and the means to gain public understanding of the many ways that wildland resources contribute to the general welfare.

Wildlife habitat must be improved if future wildlife-associated recreation demands are to be met.

Fire Protection

Wildland fires continue to take their toll of lives, homes, and natural resources in California. In spite of more powerful attack tools—including air tankers, fire retardants, and helicopters—about 5 percent of the fires still defy early control; they cause about 95 percent of the damage. The *big* fire is still our greatest challenge. Man-caused fires are on the increase. Of growing concern is the fact that, in some areas, 20 to 30 percent of the man-caused fires are started by children. The stockpiles

A large variety of recreational demands and a growing number of people who recreate threaten the quality and nature of the wildland environment.



Present fire protection policies and practices mean that dead fuels continue to accumulate from natural causes, such as windfall and dieback of timber. Economic ways must be found to reduce these hazards.

of dead fuels continue to accumulate from natural causes such as windfall and dieback. Timber harvesting and cultural measures often increase fire hazards. Prescribed burning and other techniques need to be perfected to reduce fuel accumulations. The development of such techniques must consider forage, water, and timber output as well as such environmental problems as air pollution. There is no doubt that the potential for disastrous fires in California is expanding much faster than our ability to cope with it. There is ample reason to urge continued research in fire prevention, fire suppression, and hazard reduction.

Pest Control

Concern for the impact of chemical insecticides and other pesticides on the total environment continues. Research aimed at developing target-specific insecticides that break down rapidly and minimize environmental contamination has been strengthened, along with the development of more precise application techniques. Continued effort to provide safe, non-persistent treatments is desirable. Greater effort is needed in research on biological control techniques—the use of synthetic attractants, sterilants, virus diseases, hormones, and the natural predators and parasites of destructive pests. The goal is fully integrated control based on management of insect populations.

The need for genetically improved tree stock for forest regeneration calls for stepped-up research on ways to reduce damage by insects that infest cones and seeds of forest trees. We also need to develop genetic tree strains resistant to specific diseases and insects.

We know that air pollution affects forest vegetation. Trees are dying from smog damage in southern California, and the extent of damage to other wildland vegetation is only vaguely known. The small effort now devoted to research on this problem is not sufficient to evaluate the damage or to suggest remedies.

The big fire that destroys wildland resources and man's improvements is still the greatest challenge facing fire control administrators.

There is a need to develop insecticides which are specific to the insects being controlled and which break down rapidly, minimizing environmental contamination.

Examples of Research Progress: 1964–1968

Research programs of state and federal agencies have been realigned where possible since 1963 to keep ahead of developing trends in wildland problems. Substantial progress has been made in solving some problems, barely a start on others. The list that follows highlights the nature and scope of program accomplishments in the past five years. It is not intended to summarize all research that has been done. Publications of the agencies cooperating in this plan (see *Foreword*) should be consulted for additional details.

Wildland Soils

- Soil-vegetation surveys covered 1.4 million acres. Five descriptive reports and maps, covering 20 quadrangles of 7½-minutes each, were prepared.
- Fertility status (nitrogen, phosphorus, and sulfur) was determined for nine key soils of Sacramento Valley foothill ranges.
- Erosion hazard ratings were determined for over 200 wildland soils.

Timber Growing and Harvesting

- Small clearcut openings, either narrow strips or small patches close to an abundant seed source, show most promise for regenerating old-growth red fir and white fir stands.
- Forest trees have several biological advantages which allow much more efficient selection of outstanding trees in the second generation, compared to crop and animal breeding. This will make tree breeding more feasible than previously estimated.
- Planting trees and sowing seeds by hand and by machine were compared for brushfield reforestation. After clearing the brush, costs were nearly equal for planting trees and sowing seeds, both by machine; hand seeding cost four times that of machine seeding; and hand planting six times as much as machine planting.
- Physiological grades were developed for ponderosa pine and Douglas-fir seedlings in terms of root regenerating capacity.
- Brush removal from a scattered pole-sized stand of ponderosa pine significantly increased diameter and height growth of released trees.
- Dense plantations of ponderosa pine were shown to suffer greater snow breakage than more open plantations. Snow breakage was concentrated on the tallest trees, thus increasing the seriousness of the damage.

Soil-vegetation surveys have been extended and descriptive reports and maps prepared for 1.4 million acres of California's wildlands and rural areas during the past five years.

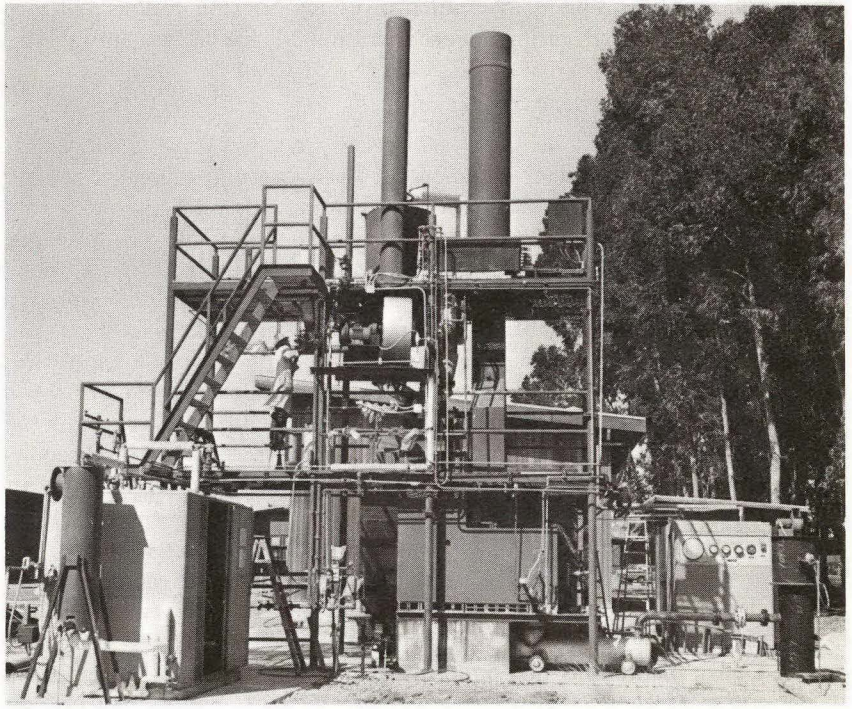
Forest Products

- Analysis of the recovery furnace operation of the kraft pulping process indicated that through both equipment and process modifications a very significant reduction in emission of noxious odors can be achieved, and industrial chemicals can be produced from the pulping residual.
- A computer program model for scheduling cutstock factories indicated that sampling, sorting, scheduling, and their interactions can affect net value of the end product by as much as 10 per cent.
- Another processing model, for drying wood, showed opportunities for increased efficiency in selecting a kiln schedule to minimize production costs and maximize value.
- Log grades developed for eastern hardwood species for the purpose of indicating expected quality of lumber yield have been found applicable, with minor modifications, to major California hardwood species.
- The use of microwaves as a source of energy in combination with hot air to dry both veneer and thicker wood material is both technically feasible and results in a more uniformly dried product, as compared with conventional methods of drying.

Range Management

- A guide for converting chaparral areas to grassland was published.
- On California annual-plant ranges, yearlong moderate grazing showed advantages over seasonal grazing systems in terms of grazing capacity and management economics.
- Rest rotation grazing on perennial grass ranges resulted in improved range condition and maintained cattle production at about the same level as season-long grazing.

New methods for planting forest tree seedlings, such as use of plastic "bullets", have helped decrease the cost of reforestation.



This experimental pyrolysis combustion unit helped show how noxious odors can be reduced in the recovery furnace operation of the kraft pulping process and also how industrial chemicals may be produced from the pulping residual.

- An electronic instrument for estimating vegetation yield was developed and is being tested for practical use.

Watershed Management

- Accelerated surface soil erosion after fire in southern California brushfields was shown to be due in part to formation of a hard-to-wet layer of soil a few inches below the soil surface which strongly inhibited or prevented water penetration. Preliminary tests suggest that application of wetting agents may increase water percolation into the soil, reduce soil erosion, and accelerate establishment of new plant cover.
- On southern California mountain slopes exceeding 80 percent, conversion from brush to grass greatly increased erosion due to numerous small landslides.
- Analysis of suspended sediment loads in streams showed that improperly located or constructed roads are more responsible for accelerated erosion than cutting and logging of trees.
- Mass erosion processes, both landslides and creep of the entire mantle in unstable soils, were shown to be major contributors of the heavy sediment loads of North Coast streams.

Studies showed that yearlong moderate grazing of California's annual-plant ranges has advantages over seasonal grazing systems.

- Evaporation losses from snowpacks were reduced up to 90 percent when hexadecanol, an evaporation suppressant, was applied to the snow surface.

Accelerated soil erosion after fire in southern California brushfields was found to be due in part to formation of a hard-to-wet soil layer a few inches below the surface.

- A radioisotope snow gage, developed to study the physics and behavior of snowpacks, shows promise for use in forecasting water yield and flood flows.
- Some species of chaparral were shown to add as much as 50 pounds per acre of nitrogen per year to the site.

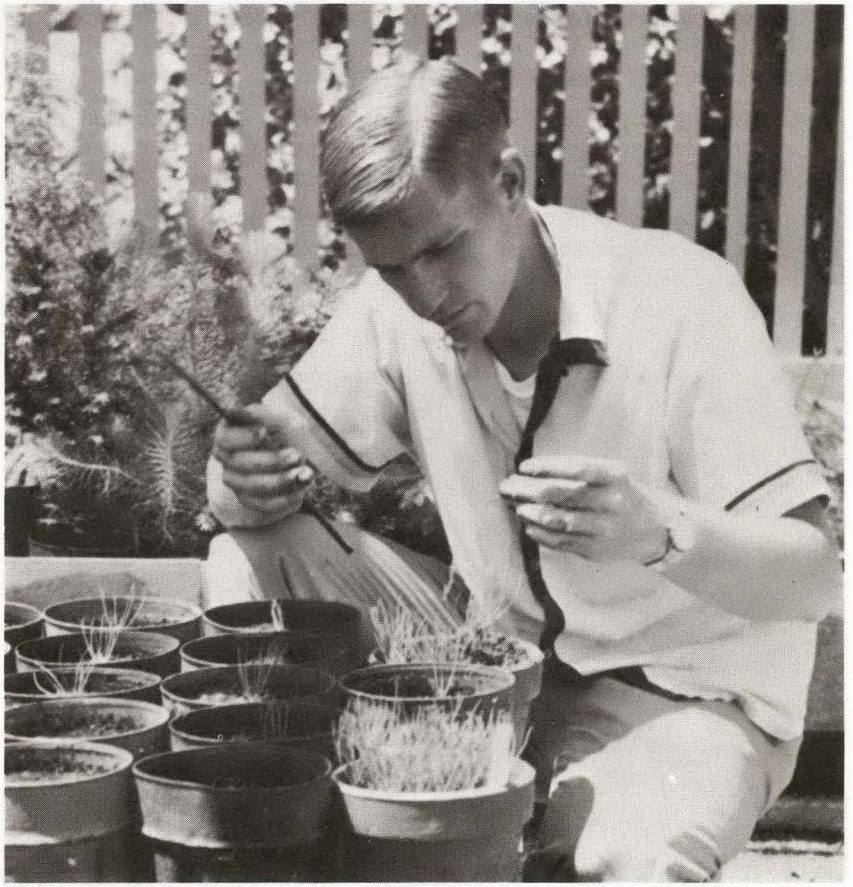
Wildlife Habitat

- After four years of study, use of cattle grazing to reduce bunchgrass on deer winter range shows promise as a means to encourage browse plants favored by deer.
- The rise and fall of a beaver population in a Sierra Nevada watershed has been followed continuously for 15 years. With exhaustion of the aspen stands, the population dropped to a low number of animals that survive by harvesting willow on a sustained yield basis.
- Six fungi capable of causing disease were isolated from dying bitterbrush plants. One or more of these are believed responsible for the bitterbrush dieback on thousands of acres of deer range in northeastern California.

Palatability and nutritive value of deer forage was determined for several browse species in northern California.

Wildland Recreation

- A mathematical model and computer program have been developed to help estimate the effect of changes in urban population, travel routes, and the number of recreation sites on recreation use of wildlands.
- Many different species of trees and shrubs are being tested, along with cultural practices, to aid in the maintenance and rehabilitation of heavily used recreation areas.



Trees and shrubs, along with cultural practices, are being identified for use in heavily used recreation areas.

- Elements of visual analysis have been defined for use in forest landscape management. Six factors of observation and scenic composition are related to resource management: distance, light, topographic form and contrast, spatial definition, observer position, and sequence.

Wildland Economics

- A computer-oriented system for producing map overlays and other resource information has been developed to aid forest managers in planning and making wildland management decisions.
- A resources allocation model (RAM) is being developed to aid wildland managers in weighing the many factors in multiple-use planning; it provides the means to capitalize on high-speed computers and modern mathematical approaches.
- A computerized system for planning and designing a large-scale reforestation program was developed. In a test case, the model gave a 17 percent increase in program efficiency compared to conventional planning methods.
- Econometric studies provided short-range and long-range forecasts of market characteristics such as price and consumption for a wide range of forest products. In addition, they provided a rigorous explanation of market behavior.
- Production and inventory planning studies demonstrated how sawmills and other wood processing plants could use mathematical programming techniques to plan inventories and production so as to maximize net monetary returns.

Characteristics of mass fires were identified for civil defense and wildland fire protection agencies.

Forest Fires

- Fire prevention studies in Butte County showed that personal contact is essential to obtain conformance with state fire laws; this conclusion was confirmed by similar sociological studies in Oregon and Utah.
- Youngsters of 10 years or less were shown to be a major target of fire prevention work because they are responsible for three-fourths of the fires started by children in California, or as much as 15 to 20 percent of all man-caused fires in some areas of the state.
- Studies in northern and southern California have helped develop new principles for fire prevention signs in terms of messages, use of symbols, and sign color, size, and shape.
- Computer-assisted dispatching of fire crews moved into the pilot testing stage as the first step in operations research aimed at a systems approach to planning and performing wildfire control.
- Long-term fire retardants, based on ammonium sulfate and ammonium phosphates, proved as effective when cascaded on wildfires from air tankers as they did on laboratory test fires. Controlled application of retardants prevented spot fires and slowed combustion in prescribed burning of logging slash.
- Basic studies clarified the nature of combustion in cellulosic fuels and the role of fire retardant chemicals in altering the combustion process.
- A series of 5- to 50-acre experimental fires provided useful data on mass fire characteristics for civil defense and forest fire agencies.

- Several techniques were developed to aid burning of logging slash, including grenade launchers, electrical ignition, and portable incinerators.
- Prescribed burning techniques were developed to maintain low fire hazard conditions in even-aged ponderosa pine and mixed conifer forests.
- Studies of low-growing and slow-burning shrubs for fuel-breaks were expanded to include several promising native plants: creeping sage, woolly nama, and saltbushes.

Forest Insects

- Artificial sex attractants for bark beetles have been synthesized and have shown some promise as a method of control in field tests.

Artificial sex attractants show promise for controlling the damaging activities of bark beetles on forest trees.

- Techniques using aerial photography and "within-tree" sampling methods have been developed for the western pine beetle which, for the first time for any bark beetle, permit accurate evaluation of timber losses and bark beetle populations.

The components of smog that damage forest trees have been identified.

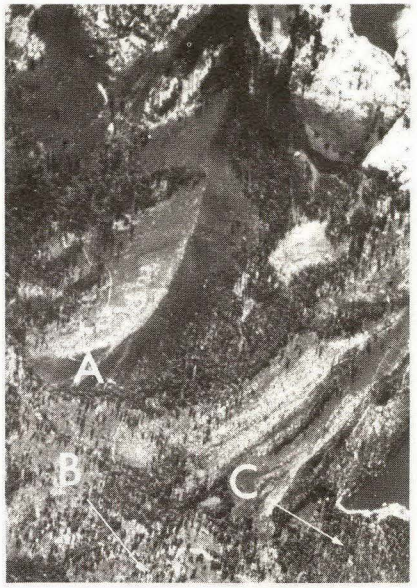
- A carbamate insecticide has been found suitable for use against the spruce budworm. Rapid breakdown and the minute quantities required eliminate adverse effects on the forest environment.
- A systemic insecticide for use against the ponderosa pine seed worm has promise of saving valuable seed crops in seed production areas and seed orchards.
- Needle miners that have destroyed lodgepole pine forests in Yosemite National Park were shown to survive unfavorable conditions in isolated environmental "niches"; the finding may help thwart epidemic attacks when conditions over wide areas improve for the insects.
- Increasing bird populations through the use of artificial nesting boxes was demonstrated to be a feasible means of reducing forest insect populations.

Forest Diseases

- The components of smog that damage forest trees have been identified and the tolerance of several native conifers is being studied to help develop or find resistant strains. Color aerial photographs proved effective in appraising smog damage. Other studies showed that smog injury predisposed ponderosa pine to further damage by bark beetles.
- Forest pathologists determined that dwarf mistletoe does not seriously infect small red fir trees beneath badly infected old trees until the younger trees reach a height of about 3 feet. This finding, coupled with the fact that the red and white fir forms of mistletoe do not cross-infect, should help foresters control the spread of this disease through proper management of fir forests.
- The danger of certain nursery root rot diseases being spread to the forests by means of planted trees has been dispelled.
- Studies which showed that tree uprooting and bole failures caused the most injuries to humans in recreation areas emphasized the importance of detecting and removing hazardous trees.

Remote Sensing of the Environment

- A research team has been formed to investigate new techniques in aerial photography—films, camera, filters—and in use of other remote sensing devices that do not depend on visible light. The goal is to help wildland managers obtain resource information more quickly, with greater accuracy, and at a less cost.



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Sensitivity: 340–500 mμ

Film: Infrared
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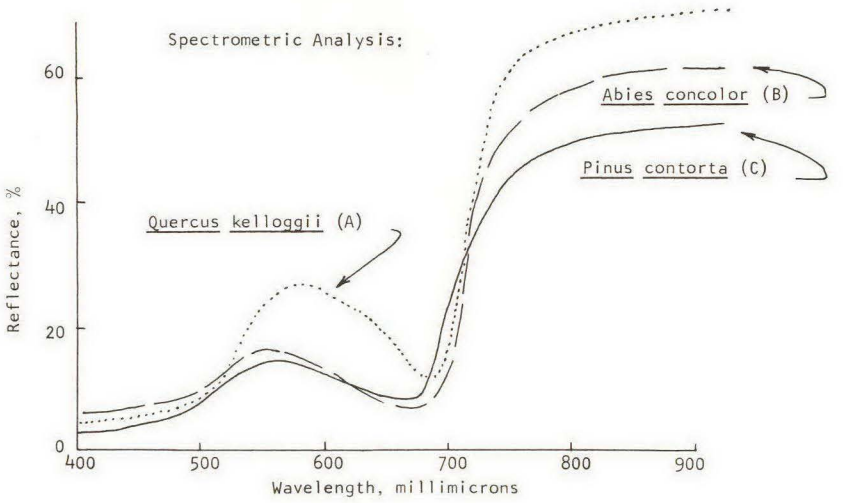
Sensitivity: 700–950 mμ



New remote sensing techniques in aerial photography have been developed to help wildland managers obtain resource information more quickly, more accurately, and at less cost.

- The same research team has demonstrated how wildland resources, including timber and range, can be inventoried from multiband photographs taken from earth-orbiting spacecraft.
- Remote sensing researchers found that ponderosa pines infested with bark beetles have higher foliage temperatures than healthy trees, extending hope that sensitive airborne thermal scanners can detect infested trees before visible symptoms occur.
- A new sampling technique and large-scale color aerial photographs permitted survey of Douglas-fir bark beetle damage on 1.6 million acres of timber, at 1/100th the cost of a conventional survey without these advanced methods.

Level of Research Effort

It is apparent that headway is being made in the attack on some crucial wildland problems. But a review of the manpower devoted to wildland research (Table 1) indicates that in many subject areas the level of effort has not kept pace with readily recognized needs. The Wildland Research Planning Committee in 1958 recommended an immediate goal of 3,157 man-months of scientific manpower. Ten years later that total had not yet been reached.

Some new lines of work not planned in 1958 were started after 1963—notably in remote sensing research and in evaluation of insecticides. Reorganization of research programs to reduce duplication of effort and to capitalize on work done elsewhere has helped sustain important studies in California. But inflation and austerity budgets have forced cutbacks or prevented expansion in most areas of research. In the light of wildland environmental problems recognized today, the 1958 goals were inadequate. Yet we have achieved only 78 percent of the research needs recommended ten years ago.

A small start in air pollution research related to wildland management problems was more than offset by reductions in other research aimed at control of destructive agents. Watershed management research fell below the 1963 level, and timber management research remained at about the 1963 level—even though the need for improvement of management practices in these complex, interrelated fields has become more widely recognized. And expansion of other studies to provide the ecological and economic knowledge for maintenance of production, income, and recreation opportunities has been slow at best.

Considering research needs identified during the course of this review, the Wildland Research Planning Committee recommends new goals totalling 5,456 man-months of scientific manpower. This level of effort calls for an expansion of 2,990 man-months to meet high priority research needs for planning and management of the state's wildland resources. We believe expansion is urgent. Surely the state which has been in the forefront of research and development in nuclear energy and space exploration can, and should, respond more effectively to the challenge of resource management in California's wildlands.

TABLE 1.—PROFESSIONAL MANPOWER, IN MAN-MONTHS, DEVOTED TO WILDLAND RESEARCH IN CALIFORNIA, AND MANPOWER NEEDS, IN SPECIFIED YEARS [1]

Research area	*Recommended 1958 goal* [2]	*Achieved 1958* [2]	*Achieved 1963* [2]	*Achieved 1968*	*Recommended 1975 goal*
Wildland soils	329	173	201	84	228
Timber growing and harvesting	422	182	286	288	840
Forest products	186	86	145	276	552
Range management [3]	447	345	407	228	480
Watershed management	354	174	250	216	692
Wildlife habitat [3]	----	----	----	126	312
Inland fisheries [4]	----	----	----	24	144
Recreation	139	103	112	168	336
Wildland economics	296	140	220	120	240
Forest fires	488	224	391	420	576
Forest insects	307	187	216	270	408
Forest diseases	189	99	108	126	360
Remote sensing [4]	----	----	----	120	288
Total	3,157	1,713	2,336	2,466	5,456

[1] Includes research efforts of the following agencies: Pacific Southwest Forest and Range Experiment Station, and the California Region, Forest Service, U.S. Department of Agriculture; Western Region, National Park Service, and the California State Office, Bureau of Land Management, U.S. Department of Interior; Agricultural Experiment Station, University of California; California Division of Forestry.
[2] From "Wildland Research Plan for California", Rev. 1964.
[3] Range and wildlife habitat management were lumped in the 1964 revision of the *Plan*.
[4] New since 1964 revision of the *Plan*.

Needed Additional Research

Managers and administrators of California's wildlands, both public and private, were asked, "What additional or strengthened research do you think is necessary to give you the knowledge and tools you need to provide the products, services, and type of environment required by the people of California?" Research specialists also submitted what they considered was urgently needed. One common thread that ran throughout the statements of managers, administrators, and researchers was the need to treat the many facets of the wildland as a total ecological sysem, an interrelated and interacting biological community responding to its environment. Every action within this wildland ecosystem—be it initiated by nature or man—has a resultant reaction on all other parts of the total system. Some of these interactions are known; most are not.

The *Wildland Research Plan for California* recognizes that the many facets of the wildland environment must be treated as a total ecological system and expresses the research needs related to the biological interactions and interrelationships within that environment.

There was also widespread recognition that the solution of many problems requires work to improve knowledge of our dependency on wildland resources. This involves surveys of public expectations, attitudes, and behavior in relation to the environment and its management—and corollary surveys among wildland managers. It also requires evaluation of methods to resolve conflicts between the public and land managers, and development of educational programs to help all segments of the population learn how to use California's wildlands in harmony with their natural surroundings.

The research needs related to interactions in the environment are the chief concern of this revision of the *Plan.* The Wildland Research Planning Committee has called for increased effort on studies which will foster understanding of public wants and our ability to satisfy them, but the committee has concentrated on physical and biological knowledge needed to maintain and enhance environmental quality. Besides the broad subject areas listed in earlier reports, this revision of the *Wildland Research Plan for California* includes three additional research areas—wildlife habitat, inland fisheries, and remote sensing—not singled out in 1964.

WILDLAND SOILS RESEARCH

Soil is basic to all elements of the wildland environment. Knowledge of soil types, their distribution, their relation to vegetation types, their erodibility, and their management is fundamental for much other research. Studies of wildland soils should:

Expand, accelerate, and improve the classifying, characterizing, and mapping of all wildland soils; identify the suitability of each soil type for various land use capabilities, singly or in combination.

Strengthen studies related to the erodibility of soil types and to methods of reducing natural or man-caused erosion. Give special attention to the highly erodible granitic soils in the Cascades, Sierra Nevada, and southern California mountains and to the blue clay soils of the Coast Range.

Seek plant species adapted to soils on road cuts and fills, on natural landslides, and on areas to be converted from brush to more useful plant species, to provide soil stabilization and a pleasing landscape.

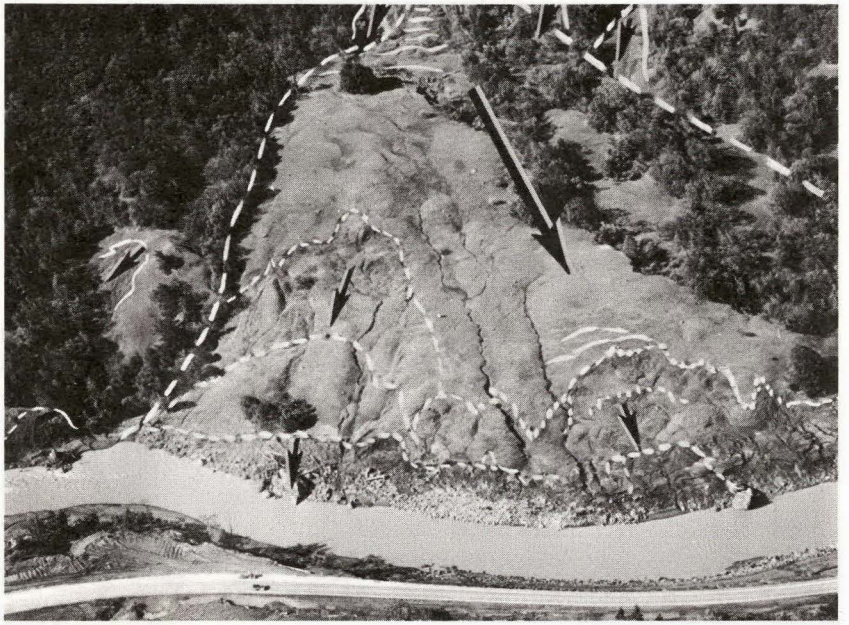
Learn more about how different land management practices and uses affect soil properties, productivity, and behavior.

TIMBER GROWING AND HARVESTING RESEARCH

A. *Forest Tree Improvement*

Forest tree improvement research is concerned with finding or creating trees better suited to man's needs. This may be done by developing hybrid strains, by using exceptional naturally-growing trees to produce seed for reforestation, and, most effectively, by using the best offspring of these exceptional parents to supply seed for reforestation. Such trees may combine superiority in form, growth, wood quality and quantity, disease or insect resistance, adaptability to sites where tree establishment has been historically difficult, low susceptibility to windthrow, or other desirable characteristics. Needed research should:

Continue the study of the genetics of forest trees to determine the variation of desirable characteristics in different individuals and strains, the inheritance of genetic characters, and the extent to which species and strains can be improved through within-species crossing so as to produce superior trees.



Studies must be strengthened in how to reduce natural or man-caused soil erosion.

The program of identifying outstanding forest trees as parent seed sources and of determining how to increase their seed production must be intensified.

Intensify programs directed at identifying outstanding individual trees and geographical and elevational races; increase seed production of selected parents by learning the physiological and biochemical processes that affect sexual reproduction in trees and thereby determining how young trees can be brought into vigorous and regular reproduction at an earlier age.

Provide economic evaluation procedures and guidelines that would enable wildland managers to decide the value of a local tree improvement program for a variety of land use purposes.

B. *Improved Seedling Establishment*

Survival of tree seedlings, whether naturally or artifically established, is difficult in California because of the state's long, dry summers. Another problem is the abundance of brush or grass-covered land in California's mountains which should be growing trees for esthetic reasons, better soil and site protection, regulation of streamflow, and timber production. Research needed to solve these problems should:

Find more effective and economic ways of preparing brush or grass-covered sites for natural or artificial seeding and planting; give special attention to decreasing costs of reforesting areas not adequately stocked with trees.

Determine the effectiveness of "nurse" trees or other plants, such as pine and ceanothus species, on the survival of Douglas-fir seedlings on poor quality sites.

Find cheaper and more effective means of releasing young timber species growing under brush, consistent with requirements of the total wildland ecosystem.

Investigate timber management practices designed to induce more abundant and regular seed crops.

Learn how to reduce or eliminate destruction to tree seeds and seedlings by animals and birds.

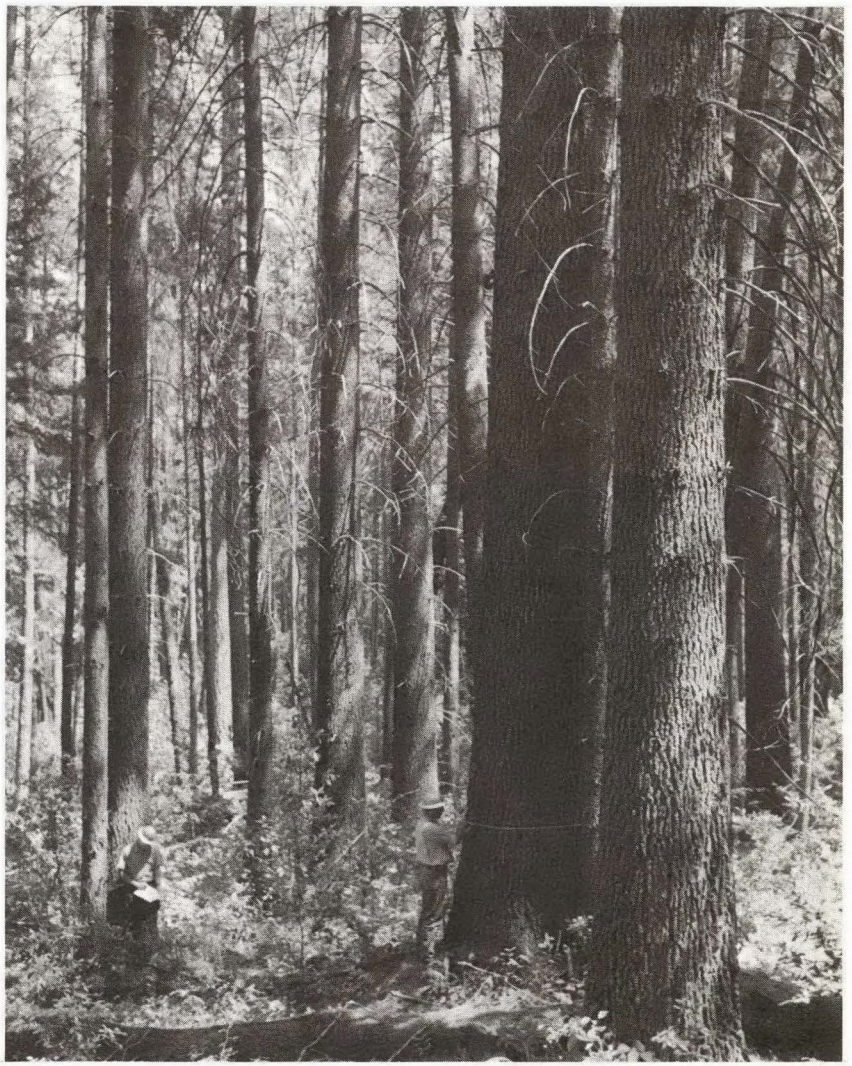
Strengthen studies to determine what seed sources to use for planting in different localities. Determine whether selection for early survival and growth will produce strains adapted for reforestation on difficult sites.

Continue the study of seed and seedling physiology to find ways of assuring a greater probability of survival in reforestation projects.

C. *Manipulation of Growing Stock*

In wildland areas tree stands must be managed to obtain a desirable composition, production goal, and/or financial level in accordance with land use and resource allocation objectives. For each timber-growing site, timber type, and management objective there is a most favorable spacing and species mix of trees at each age of the stand. Needed research should:

Continue to define desirable stocking levels and thinning schedules for each age of each forest tree type, for each site classification, and



Attention must be given to learning how to manage young timber stands more intensively.

for each land- and resource-use objective. Give particular attention to the management of young stands of timber.

Establish the costs and benefits of practices to improve site quality, including fertilization and use of specialized equipment.

Study the special requirements for optimum spacing and culture of trees growing in high-value, developed areas (e.g., Lake Tahoe in northern California and Big Bear Lake in southern California) and in city and town settings—to provide healthy, vigorous trees for esthetic purposes in situations where soil compaction, windthrow and limb breakage, and forest pests create special problems.

Continue to develop the economics and quality improvement practices of managing trees for wood production by controlling knot and defect content, diameter growth rate, fiber length, and wood density.

D. *Prediction of Growth and Yield*

How forests are managed and harvested depends largely on the characteristics of the forest: the species and numbers of trees, their present and predicted growth, and the yield of wood products or other goods and services. Research is needed to:

Develop more economic, efficient, and accurate inventory methods —including the use of automatic data processing—for different forest types intensively managed to meet timber or other goals.

Provide growth and yield tables for managed young-growth timber stands, particularly in mixed conifer, uneven-aged forests.

Provide better predictions of effects of management practices on the yield of timber from forest land, as well as on wildlife, water, and recreation.

E. *Methods of Timber Harvesting*

Timber harvesting, as a part of forest management, must maximize production compatible with maintaining the highest quality wildland environment and its associated ecosystem. Research studies should:

Develop timber growing and harvesting systems based on ecological principles developed for each forest type and managerial objective. Systems for manipulating and harvesting forests must be designed to provide stand structures and compositions which are compatible with multiple use of wildlands and which provide suitable seedbeds for new crops of trees.

For areas where clear cutting has been found to be ecologically necessary, design harvest methods that provide a more pleasing appearance than has been achieved in the past; investigate the feasibility of alternate harvesting methods which will maintain timber-growing benefits and obtain a higher degree of public acceptance.

Continue the design and evaluation of new kinds of mechanized equipment for harvesting different timber types in keeping with ecological and broad management needs; study especially the feasibility and economy of more automated equipment.

Determine the effect of California's Forest Practice Act in conserving and maintaining the productivity of the state's timberlands.

Determine the public's knowledge and attitude about raising and harvesting timber as a crop and about using timber as a source of products which enhance the standard of living. Design educational programs to improve the public's knowledge about such matters.

FOREST PRODUCTS RESEARCH

Forest products research must deal not only with increasing demand for wood and fiber products, but also with a changing raw material base and competition from other materials. The needs include:

Management systems for harvesting timber must also provide for multiple use of the forested area and must be based on ecological principles developed for each forest type.

A. *Research in the Efficient and Complete Use of the Forest Crop*

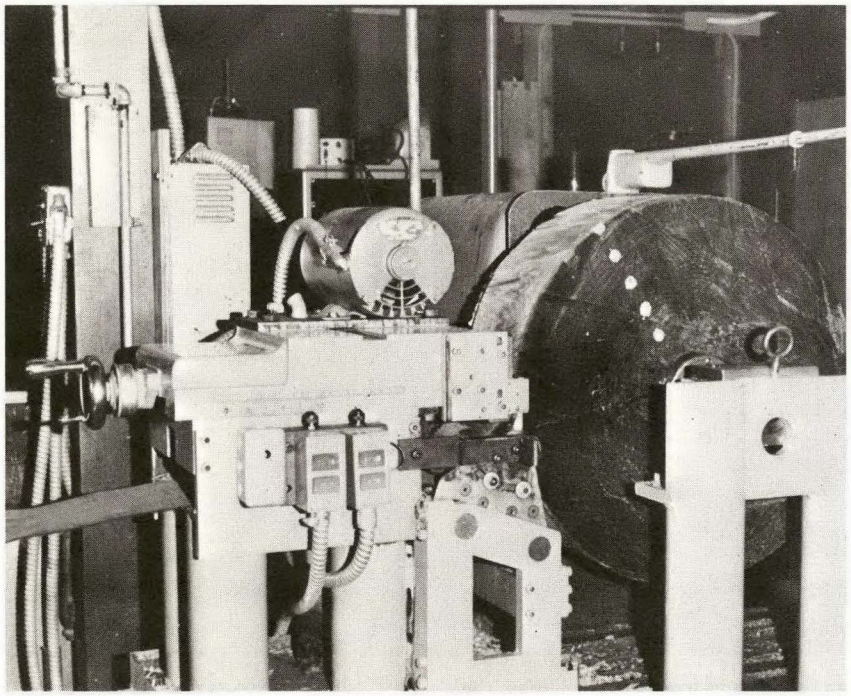
Improve knowledge of the physical, mechanical, and chemical properties of California tree species, including minor species.

Develop engineering information which will enable using wood more efficiently and with greater reliability in structures.

Improve the physical and chemical utilization of harvesting and manufacturing residuals (tree tops and branches, bark, lignin, etc.). Advance the use of this material for fiber, sheet, extruded and formed products, and production of chemicals for industrial and other purposes.

Increase the utilization of young-growth and minor species both for recognized and new products.

Find techniques to protect wood products against fire and attacks by insects and disease.



New uses and production processes must be developed for young-growth timber.

Increase knowledge about California's brush species: physical and chemical properties, the possibilities of fiber and solid wood particle processing, and the economics of harvesting and processing.

B. *Research in the Improvement of Existing Processing Systems and the Development of New Systems*

Improve the machining of wood by all kinds of cutting tools with the objective of reducing residue, producing better quality products, and reducing costs.

Analyze partial and entire wood manufacturing systems to help determine the most adequate, economical, desirable, and efficient utilization and conversion systems.

Develop pulping and associated fiber processing systems to improve yield and reduce costs.

Improve systems for drying and treating wood.

Seek advances in basic knowledge of wood constituents and processing procedures which will reduce or eliminate air and water pollution resulting from wood processing.

RANGE MANAGEMENT RESEARCH

A. *Characteristics and Requirements of Range Vegetation*

The use and management of California's range vegetation depends upon adequate knowledge of the individual plant's needs during its life cycle and of the interrelationships between plants and their environment, including the effects of changes brought about in that environment by nature or man. Research needs to:

Continue determining the requirements of important range plants for heat, moisture, and nutrients and the effects of competition from other plants and from animals.

Strengthen studies of the nutritive value and digestibility of forage species for domestic livestock and wild animals.

Determine the effects of air pollutants on forage plants.

Find plants which are adaptable to poor sites for use both in erosion control and as animal feed; develop economic means of establishing those plants on such sites.

Intensify studies of disease organisms which have killed bitterbrush on thousands of acres in northern California.

Conduct basic studies to determine the nature and control of insects and diseases which threaten wildland range plants important to the well-being of domestic livestock and wild animals.

B. ***Livestock-Wildlife-Vegetation Relationships and Management Systems***

Research is needed to determine how domestic livestock and wild game animals can be managed and utilize the same wildland range in a manner that will conserve a high quality wildland environment for all needs and purposes:

Develop range management systems that will enhance other land uses and values.

The economics of using non-persistent herbicides to control brush regrowth in areas converted to grass for livestock grazing must be determined.

Determine the number of animal-months of grazing that can be obtained from a variety of land management practices; find the most desirable and economic practices.

Investigate how the number, type, seasonal distribution, and eating habits of domestic and wild animals affect the quality of the wildland range habitat; and, conversely, determine how changes in the wildland habitat caused by disturbing influences, including the presence of man, affect the quality of animal life.

C. ***Improvement Practices for Grass and Brush Ranges***

Range improvement practices are concerned with grazing control, seeding, fertilization, the manipulation of existing undesirable vegetation with fire, chemicals, mechanical and biological means, and overall management. Research should:

Determine how to increase on-site water yields and benefits to range animals from vegetation type conversion.

Find economic techniques of lengthening the time that chaparral stands remain open after burning; possible methods include the use of herbicides, grazing animals, and competing plants.

Develop and test new plants for improving the wildland range habitat, including legumes and their specific nitrogen-fixing bacteria; find economic means of obtaining and successfully planting the seeds of such plants.

Conduct cost-benefit studies of fertilizing and of applying other range improvement practices on a wide variety of wildland ranges.

Make cost-benefit analyses of alternative ways of converting brushland to perennial grassland on a variety of sites; determine the optimum management system for these areas in combination with adjacent native ranges.

WATERSHED MANAGEMENT RESEARCH

A. ***Water Quantity and Quality***

Basic to the management of water production from California's wildlands is the gathering of hydrologic information, including climate and precipitation, water yield and sedimentation, infiltration and evaporation for each distinct vegetative cover type. Research of this nature should:

Determine the effects of different wildland uses and different vegetative cover types on the quality, quantity and rate of water flow produced from the wildlands.

Determine the inherent stability of various soil types and relate this information to land management practices and protection of the quality and quantity of water.

Investigate the effects of human habitation on the quality of water produced from wildlands and determine what waste water treatment practices are needed in the wildlands to protect water quality for downstream users and for aquatic life.

B. *Watershed Management in California's Brushlands*

Special problems exist where brushlands are adjacent to urban areas, where the protective brush cover is destroyed by fire or other agents, and where brush is converted to grass. Research should:

Develop management practices which will ensure soil stabilization and reduce flood runoff, especially adjacent to urban areas.

Determine which wildland sites are adaptable for conversion from brush to grass or to timber without a subsequent and resultant deterioration of the site and of the water produced from it.

Basic information is needed about snow accumulation, melt, and water runoff so as to reduce the chance of downstream flooding and to increase the quality and quantity of water production over the full year.

Study further the phenomenon of soil non-wettability on burned-over brushlands and accelerate investigations as to how wetting agents may be used effectively and economically to increase water infiltration into such soils.

Continue studies of methods to reduce the quantity of water used by various types of brush and to increase downstream water production.

C. *Watershed Management in California's Snow Zone*

The snow zone is highly important for its production of water for downstream storage and use. Research studies should:

Strengthen meteorology and snow physics research to provide basic information about snow accumulation, melt, and water runoff under a variety of climatic, vegetative, and soil conditions.

Continue studies on how to manipulate all types of wildland vegetation so as to reduce evapotranspiration losses, increase the period of snow storage, produce a more gradual water runoff, reduce the probability of downstream flooding, and increase the quantity and quality of water production over the full year.

D. *Watershed Management in California's Commercial Timber Zone*

Timber grows in California's zones of highest precipitation. How these lands are managed by man, and how they are changed by fire and other natural agents will therefore affect the water produced from them. Water production must be considered in terms of rate of flow (sudden flood run-off versus long-term, steady flow), total seasonal water yield, quality throughout the period of flow, and effects on other elements of the wildland environment. Research should:

Strengthen studies on how timber management practices affect water production and quality; and devise management procedures for unstable soils.

Investigate the effect of lodgepole pine and other tree encroachment on water production from mountain meadows.

Study the impact of removing or disturbing streamside trees and other vegetation on water temperature and quality and the effects on aquatic and animal life.

WILDLIFE HABITAT

A. *Basic Studies*

Studies are needed of mammal and bird life cycles and their role in the ecology and quality of the total wildland environment. Especially needed are studies to:

Determine the complete life cycles of mammals and birds living in California's wildlands and determine their interrelationships with each other, with man, and with all other elements of wildland ecosystems; study wildlife requirements for food, water, and cover.

The complete life cycles of mammals and birds living in California must be studied in order to understand their interrelationships with each other, with man, and with all other elements of wildland ecosystems.

Study how different wildland vegetative types should be managed and manipulated so as to enhance wildlife and at the same time enrich the total environment.

Population levels must be determined for herbivores, particularly deer, so that the damage they create to forest tree seedlings and other wildland resources is tolerable.

Study the diseases of California's wildland animals and birds and learn how they may be eliminated or controlled at a tolerable level.

Study the damage caused by disease, insects, and fire to plants which are important food sources for wildlife.

Investigate the extent and nature of damage to vegetation and other wildland resources created by herbivores, particularly deer, because of the gradual elimination of carnivores from the wildland environment; determine population levels for herbivores so that the damage they create to wildland environments is tolerable.

Learn how different wildland range types must be managed to accommodate both domestic and wild animals.

B. *Control Studies*

Develop non-lethal animal repellents designed to protect young tree plantations from being damaged by browsing deer and other animals.

Determine the economics, sociological impacts, and game management aspects of either-sex deer hunts.

Find ways of controlling damages to trees from porcupines and bears.

INLAND FISHERIES RESEARCH

The well-being of aquatic life is inexorably linked with the quality of its environment. The potential is great for expanding recreational opportunities for all types of fisheries and fishermen, for increasing economic gains, and for creating new or improved wildland fisheries habitat. Needed research should:

Evaluate the effects of wildland disturbances, caused by both man and nature, on the quality of the inland fisheries and on the abundance and characteristics of different fish species and learn how to control these disturbances so as to maintain the ecological balance of the wildland environment.

Broaden studies in how stream siltation affects the total life cycle of different fish species.

Identify methods and the economics of providing a variety of fishing experiences to meet the demands and needs of all types of fishermen.

Relate the location, range, and fluctuation of water temperatures and volumes to fisheries management and learn how to manipulate the wildland environment so as to provide favorable water quality and flow.

The effects of natural and man-caused disturbances on the quality of inland fisheries, and the control of such disturbances, must be determined.

WILDLAND RECREATION RESEARCH

A. *Research in Recreational Land Management*

Because of the increasing demand for recreational opportunities, all wildland managers must consider recreational alternatives in relation to other possible uses. To help weigh the alternatives, research should:

Determine the impact of different kinds of recreation upon the quality and nature of specific wildland environments and ecosystems.

Learn the amount and rate of recreational use each wildland type can withstand without endangering its natural condition; evaluate what management practices are needed to provide these acceptable levels of use.

Provide landscape management guidelines which will meet requirements of natural beauty and yet not be in conflict with recreational and other wildland uses.

B. *Research in Recreational Policy, Institutions, and Economics*

Both private and public land managers need to know the nature and the extent of present and anticipated recreational demands upon their lands so that they can integrate this alternative use into their overall planning economically. Research efforts should:

Study the broad requirements of people for types and places of recreation, seasonal demands, and the cost-benefits of alternative recreational facilities at a given location.

Determine how recreation fits into the local economy and affects other land uses.

Provide guidelines for controlling the activities of recreationists, through law enforcement if necessary, in order to maintain the quality of the wildland environment.

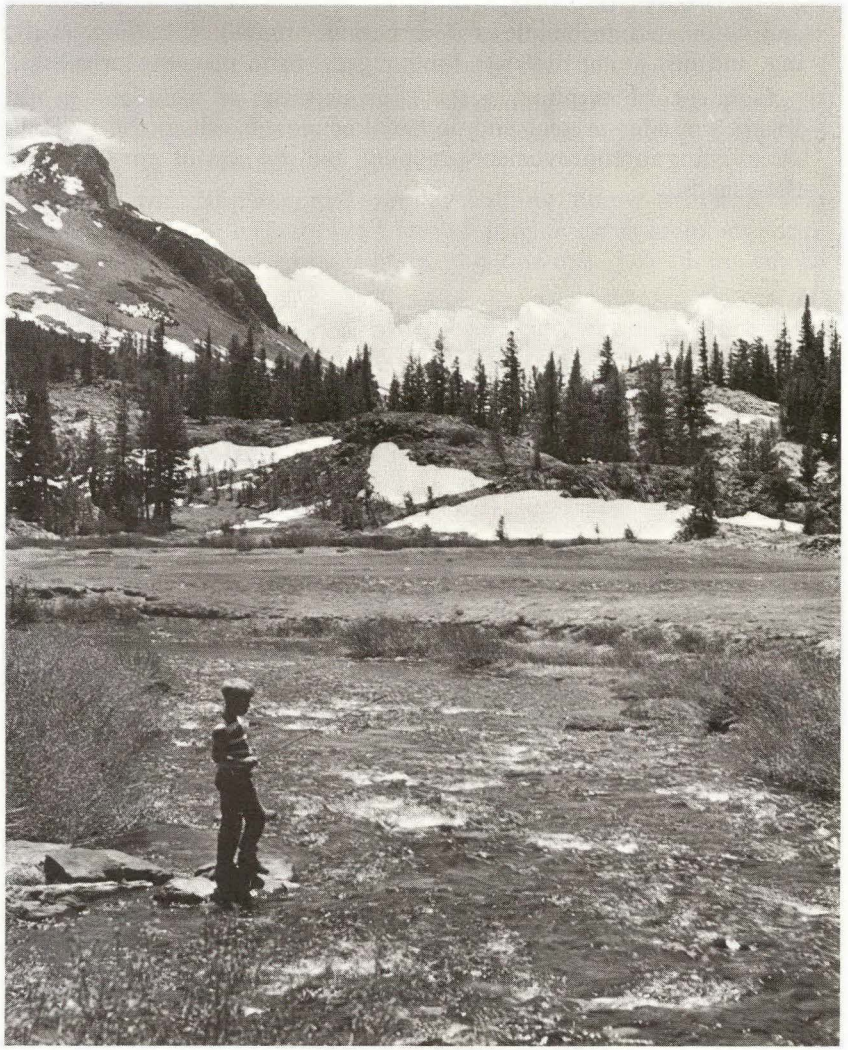
Determine the impact of various forms and levels of recreational use on the demand for public services including fire protection, policing, sanitation, and public health, and the relationship of these demands to public finance.

Keep pace with changes in the ways that people recreate; provide new designs, new standards, new concepts for meeting these changes; give special attention to the camp site facilities needed for use of truck campers, and trailers, and other recreational vehicles—and to the problems that may be created by their use.

Determine the needs and the nature of visitor information centers, where they should be located, whom they should serve, and what they should provide.

WILDLAND ECONOMICS RESEARCH

Research in the economics of wildland use and management is a continuing process. Demands for use of the wildland environment and for

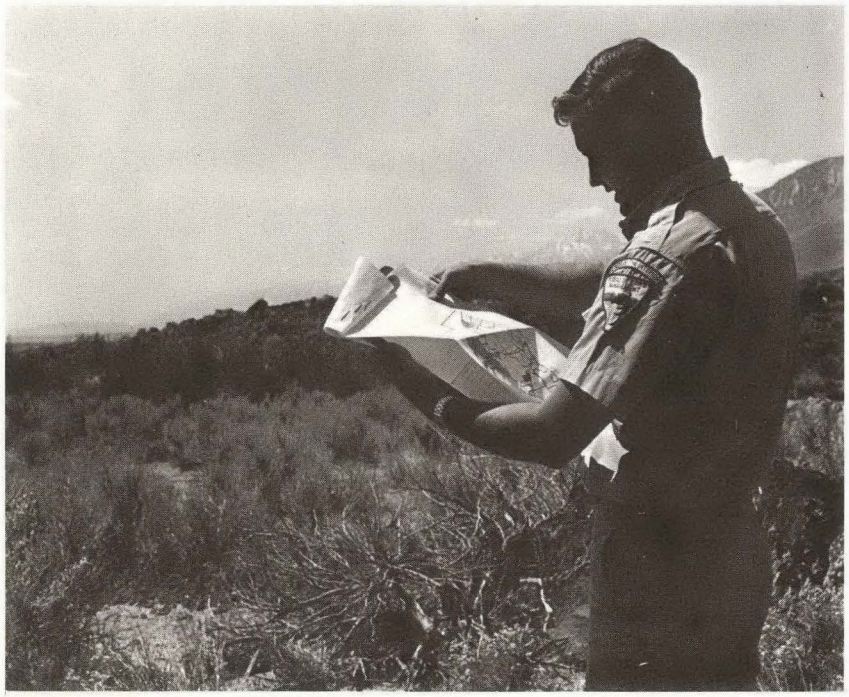


What impacts different kinds of recreation have upon specific wildland environments and ecosystems must be learned.

products derived from that environment continually change. Hence, there must be a sustained economic evaluation of this demand and of management practices needed to meet the demand. Research in this field should:

Provide more and better basic data about wildland resources for the purpose of improving management decisions; develop improved and automated techniques for gathering, compiling, storing, analyzing, and displaying this data for budgeting and planning processes.

Give special attention to the large expanses of brushland in California; consider present and potential economic values, the feasibility of investing in improvement practices, and the cost of *not* developing these lands.



Present and potential future uses of different wildland environments, including California's desert lands, must be inventoried, evaluated, and prescribed in terms that are economically as well as ecologically acceptable.

Give special attention also to the millions of acres of desert in southeastern California; inventory present and potential uses; prescribe and evaluate economically alternative management systems.

Find more accurate techniques for appraising the long-term trends of demands for wildland products and services to assist in long-range management planning and development.

Develop guidelines to enable landowners to determine the best economic use or combination of uses of different wildland types; show how timber stands of different species and age class composition may be managed for a profit.

Continue the economic analysis of alternative uses and management practices in relation to wildland resources; consider the factors of public acceptance and environmental effects relative to each alternative, including the impact of subdivision sewage and waste disposal, and other facilities for economic development.

Determine the nature of the impacts of taxes, credit, and insurance on alternative management plans.

FOREST FIRE RESEARCH

A. *Fire Prevention*

Fire prevention research studies the nature, cause, and possibilities of eliminating fire-starting sources of all kinds. It also considers techniques and practices to halt the spread of fires immediately, should they start. Research in this field should:

Strengthen studies in the social, economic, and psychological characteristics of people who cause forest fires, with special emphasis upon understanding and favorably influencing people who deliberately and maliciously set fires and the younger child who presents problems of a unique nature.

Conduct tests to determine the probable ignition and burning characteristics of a large number of specific fire-causing devices (e.g., carbon particles or hot metal emitted from engine exhausts; cigarettes) under a wide range of environmental conditions and to develop criteria for practical field use of the information.

Accelerate studies of wildland fuels, including their classification as to the probability of fire ignition, rate of fire spread, and release of heat energy under a variety of environmental conditions, and including their further classification as to the type of treatment or modification needed to prevent the start or spread of fires in the fuels, especially around communities in wildland settings.

Conduct studies of the relevance of present fire laws and enforcement techniques and the need for possible changes in both.

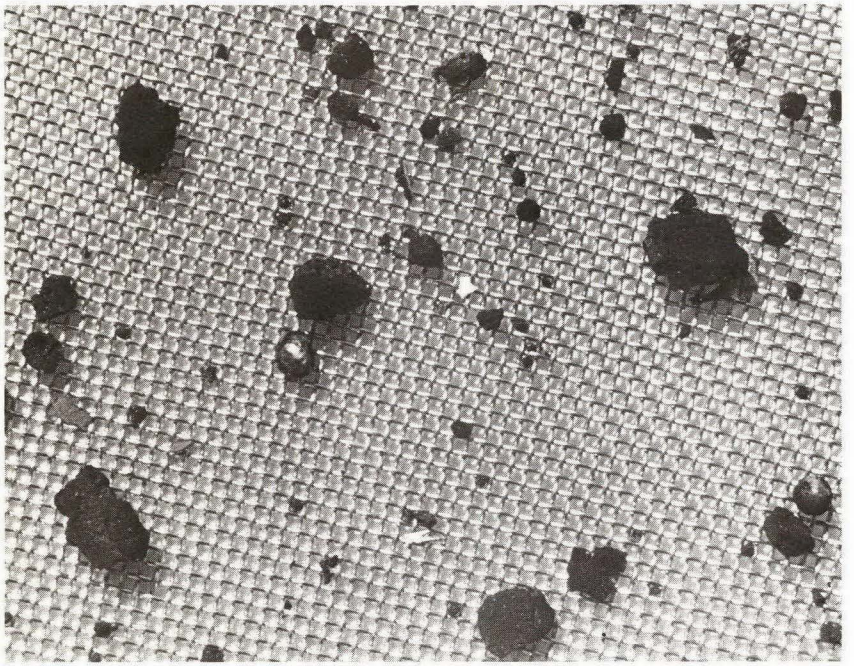
Accelerate and strengthen tests of an optimum system of fire prevention techniques for use in a representative administrative unit.

Conduct local studies aimed at identifying and modifying the physical characteristics of thunderclouds so as to prevent lightning-caused fires.

B. *Fire Control*

Fire control research covers a broad range of subjects including the detection of fires; the influence of weather, fuels, and topography on fire behavior; methods and tools used in controlling the spread of fires; and the training of people in all aspects of fire behavior and control. Research should:

Develop faster and more cost-effective systems of detecting fires under a broad range of environmental conditions, including smog.



Further tests are needed to determine the probable ignition and burning characteristics of such fire-causing agents as carbon particles emitted from engine exhausts under a wide range of environmental conditions.

Strengthen and broaden local weather surveys throughout California to provide better knowledge about climate and to enable more precise prediction of fire weather, especially of the timing and geographical extent of extremely low fuel moisture and high velocity wind.

Increase studies of fire behavior, with special emphasis upon producing guidelines for recognizing those environmental conditions that are likely to produce the large, potentially destructive fires.

Accelerate the development of dispatching and fire management systems for faster and more meaningful decision making, using the techniques of automated data processing.

Reduce the time required for firefighting crews to reach fires through the study of alternate transportation systems including large helicopters, large transport aircraft, and one-man propulsion equipment.

Conduct and broaden studies of both long-range and short-range effects of firefighting on the physiology of firefighters.

Find more effective means of training firefighters in the complex science and art of firefighting and find faster, easier, and more certain ways of extending research results into practice.

Strengthen basic studies in the nature of the combustion process and find more effective means for modifying this process.

Continue to develop economic, esthetic, and ecologically balanced techniques of reducing wildland fuels to a tolerable level and of maintaining that level on a continuous basis.

Expand studies on how to economically control regrowth and reseeding of brush species on cleared fuelbreaks and other areas; study the physiological effects of chemical herbicides on brush species, as well as on other plants and animal life in the same ecosystem, and seek alternatives such as biological control.

Define and measure the probable physical outputs of the individual and combined components of different fire protection systems, including men, equipment, and fire defense improvements.

Determine the optimum staffing patterns needed on the different types of fire control crews and identify the most economic and effective numbers and combinations of these crews needed to meet local fire control objectives.

Establish guidelines for appraising fire damages to wildland resources and for estimating the value of resources saved from damage by fire as the result of fire control actions and defense improvements.

C. *Fire Use*

Fire can be a useful tool, as well as a destructive agent, in wildland management. In selected places and under prescribed conditions, fire can help create a more favorable environment and produce increased benefits from the wildlands. Much research is still needed to determine the techniques of such fire use:

Quantitative studies are needed to determine the optimum size, geographical distribution and physical outputs of different fire control crews needed to meet local fire control objectives.

Develop techniques and determine the costs, benefits and effects of using fire in different fuel types and locations for the purposes of reducing or modifying fuels, of enhancing the environment, and of increasing the quality of products to be derived from the land.

Determine the contribution of pollutants to the air from the use of fire in controlled or prescribed burning of brush, slash, and other heavy fuel accumulations and in disposing of waste material in sawmill burners and community dumps.

Strengthen studies of the weather conditions under which fire should be used so as to attain maximum safety and minimum air pollution.

Determine the effects of fire on the cycling of minerals between soil and plants.

FOREST INSECT RESEARCH

A. *Surveys*

Continuing statewide systematic surveys provide the basis for early detection, identification, and required control of both introduced and native insect species. Needed research should:

Strengthen studies to improve survey methods, including the development of more precise sampling techniques and other means of detection, in combination with disease surveys, where applicable.

Provide realistically acceptable damage loss figures for each forest insect specie, or combination of species, and for each local ecosystem.

B. *Basic Studies*

These studies are required to learn each insect specie's detailed life cycle and to determine when, where, and how it is most susceptible to control measures. They relate environmental effects to the insect's life cycle, shed light on why and when individual insect species attack only specific parts of specific plant species, and determine why individual plants vary in their susceptibility to insect attack. Research is needed to:

Continue studies designed to identify insect species, define their life cycles, characteristics and habits, their parasites and predators, and relate them to the total insect problem.

Clarify how environment and changes in environment affect insect life cycles and what factors are important in causing insect popula-

tions to increase or decline appreciably. A knowledge of these mechanisms is the key to successful insect control.

Continue to investigate what plants and parts of plants are affected by individual insect species; why susceptibility to attack varies among individual plants; how plant resistance is affected by varying degrees of insect infestation; and how plant resistance may be enhanced by artificial means.

Determine insect responses to stimuli from odors, taste, physiological characteristics, and moisture associated with host plants; and investigate the role of microorganisms in affecting those responses.

C. *Control*

Control of insect populations should progress toward integrated control, considering all potential mechanisms of population reduction, natural or contrived. This approach is particularly promising in forests through manipulation of the vegetation (timber management) augmented where necessary by biological or chemical control measures. Its application depends on knowledge of the cost-benefit ratio of alternatives and especially their impact on the total ecosystem. Research should:

Non-persistent insecticides that affect only the target insect, and not other biological elements of the total wildland ecosystem, are needed to reduce insect damages to forest trees and to valuable browse plants.

Continue to investigate the way such timber management practices as thinning, commercial logging, and slash disposal affect the buildup of insect populations, and how these practices should be modified to prevent the buildup.

Identify the kinds and abundance of natural enemies—invertebrate, vertebrate, and disease organisms—and evaluate their effectiveness in helping to control insect population. Determine methods of augmenting populations of such natural control agents and the feasibility of introducing them where not present.

Determine more completely the role of "sex attractants" in the life cycle and behavior of the insect pests with the aim of interrupting normal behavior as an aid in control.

Continue to seek selective, non-persistent chemical insecticides, including studies on relative effectiveness, development of resistance to the insecticide by the insect, and improved methods of application.

FOREST DISEASE RESEARCH

A. *Surveys*

Disease surveys, like those for insects, not only identify threats to wildland vegetation, but also point up the control needs and special problems requiring research. The work should:

Investigate methods of accelerating and improving the detection of disease attacks, including remote sensing by aerial photography and other means. Determine the feasibility of combining disease and insect surveys, where applicable.

Find ways of detecting some diseases which presently do much damage and yet are difficult to detect in the early stages of attack; special emphasis is needed on root rot detection.

B. *Basic Studies*

Basic studies are needed to identify new diseases, to learn the life cycle of each disease, to determine effective damage appraisal techniques, and to learn how individual diseases are affected by changes in their environment or by the condition of their host plants. As forest management of second growth timber stands intensifies, many current disease problems will become more severe and new problems are likely to appear. Basic studies should:

Identify the characteristics and life cycles of each disease that is potentially damaging to wildland vegetation.

Investigate those plants and environmental conditions which are most responsible for invasion by diseases.

Determine how host plants tend to defend against disease infection and how plants may be improved to resist such infection; seek plants which seem to have natural resistance to disease.

Develop methods of diagnosing damage to wildland vegetation caused by non-infectious disease agents such as air pollutants, ice, heat, drought, wind, etc.; give special emphasis to damage caused by smog.

Give special attention to the study of root rot and dwarf mistletoe, correlating their life cycles with time and methods of timber cutting, soil type, and vegetative composition.

Trees must be found which have a natural resistance to damaging diseases.

Determine the role of diseases in creating conditions conducive to major insect infestations. Increase integrated studies of the interactions between diseases, especially root diseases, and insect infestations.

C. *Control*

Additional studies are needed to find effective and economical control methods that are more acceptable in their influence on the total wildland ecosystem. Emphasis must be placed on the most damaging diseases: root rot and mistletoe. Studies are especially needed to:

Strengthen the search for biological methods of disease control so as to reduce the use of chemicals.

Investigate new chemicals which may be more effective in controlling disease but less harmful to other plants and animals.

Provide more knowledge on how wildland vegetation, especially timber, may be managed and manipulated to aid in the control of diseases.

Determine analytical means of measuring the total effectiveness of any control job and the probable required time of reworking the same area in order to maintain disease losses at a tolerable level.

REMOTE SENSING RESEARCH

Measurement and characterization of the wildland environment is fundamental to determining its quality and management. We should be able to delineate the principal wildland ecosystems in California, determine the most appropriate single use or combination of uses to meet economic and cultural needs, and identify the capacity of each system to sustain use. Ways must be found to obtain, store, and retrieve information quickly, accurately, and in necessary quantity and quality. Such information should include not only the inventory of existing resources, but also measurement of the impact of insects, disease, fire, and other disturbances on the environment. It should also include measuring the direction and rapidity of change in the condition of wildland resources to permit accompanying changes in management practices. Sensing of the wildland environment from remote platforms, such as photography from aircraft or from orbiting satellites, provides an important tool for such measurement. Research in this field is needed to:

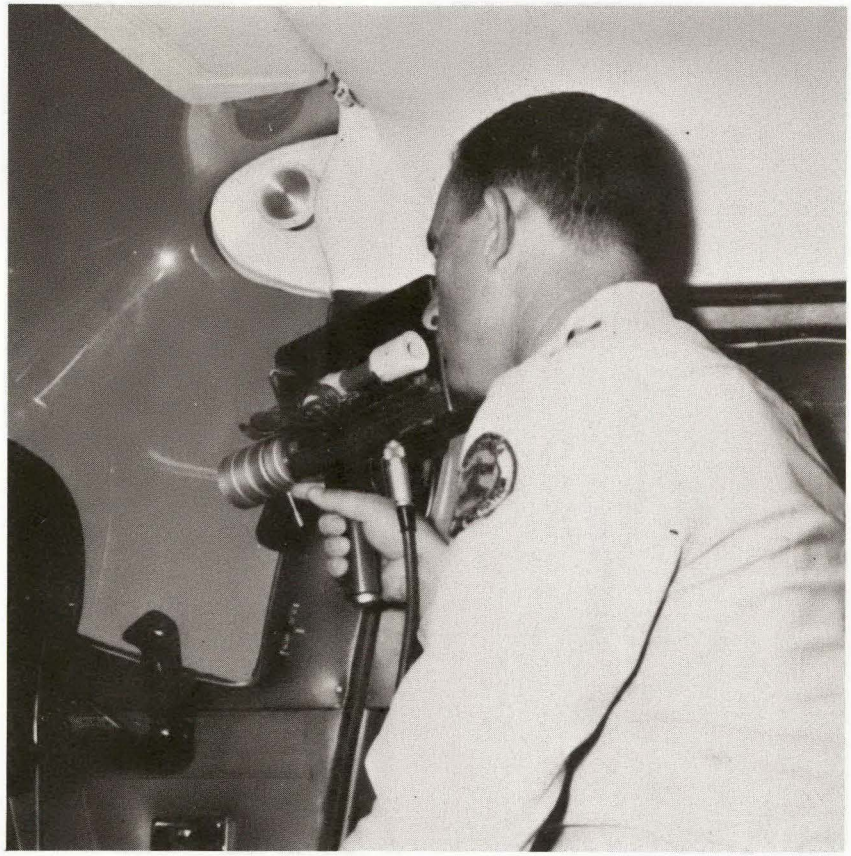
Strengthen studies in the application of different cameras and films for recording elements of the wildland environment.

Determine what sensing devices developed for other purposes may be adapted to wildland problems.

Learn how to identify and measure different vegetation types, disease and insect effects, soil types, surface geology, water quality, and seasonal changes in the environment more quickly and accurately than with present techniques.

Investigate additional uses of infrared detectors, television, and similar electronic devices to sense elements of the wildland environment.

Study how remote sensing devices can be linked economically to automatic data processing equipment to produce and display vital environmental information rapidly when needed.



Tools such as portable video equipment must be fully evaluated to learn how elements of the wildland environment may be detected and measured most effectively and economically.

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